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PERFORMANCE OF THE SCOTT AVOIX EMERGENCY OXYGEN SYSTEM AFTER EX--ETC(U)
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PERFORMANCE OF THE SCOTT AVOIX EMERGENCY OXYGEN SYSTEM AFTER EXPOSURE TO NORMAL, HOT AND COLD STORAGE CONDITIONS

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ABSTRACT

With the advent of the Long Range Patrol Aircraft (LRPA) the CP-140 Aurora, the Canadian Forces will not only be acquiring a new aircraft but a new supplemental oxygen system as well. This system is the Scott Aviox which is a solid state system that utilizes a chemical composition for oxygen production versus more conventional methods of stored liquid or gaseous oxygen. Although this type of system is not new in the aviation world, it is only now being adopted for use in the CF.

Because of the novelty of this system in the CF, this evaluation study was conducted to determine the units ability to meet criteria established in regards to reliability, production and ability to operate after being exposed to temperature extremes.

A number of the Aviox generators were activated under normal conditions and after being exposed to temperatures of -54 degrees C and + 65.5 degrees C. The performance was recorded and used as comparison data in establishing their ability to meet criteria for a similar system established in USAF MIL-E 83252 "Emergency Oxygen Supply, Chlorate Candle, Aircraft CRU-74/p".

In general the production of these generators met the established requirements. Exposure to temperature extremes altered flow rate production but not to an extent where it fell below the required minimal levels.

Dependant on further evaluations in the hypobaric chamber, there appears to be no indication that this system is not reliable and its ability to perform to required standards is such that its service in operational use should be without problem. Based on the findings in this report and dependant on results from hypobaric trials, there appears to be no reason why this system could not be utilized in CF aircraft.

SCOTT AVIOX SINGLE PAK

Introduction

1.

The Scott Aviox Single Pak is a solid state oxygen generating system designed to provide supplemental oxygen during emergency situations. This system has been adopted for use in the Canadian Forces new Long Range Patrol Aircraft (LRPA) the CP-140 Aurora, where it will be used as an emergency oxygen supply for all crew members other than those employed on the flight deck.

This evaluation was conducted to determine the unit's reliability for oxygen production and ability to operate under normal and environmental extremes which may be encountered in operational use. The environmental extremes included exposures to both hot and cold temperatures which may be encountered on the ground, as well as a cold environment simulating a decompression in the aircraft.

The units tested were compared to specifications found in USAF MIL-E-83252 "Emergency Oxygen Supply, Chlorate Candle, Aircraft CRU-74/p". These comparisons were used to establish the system's overall performance in regards to the aforementioned factors.

Background

The Aviox system is simple in design and is self-contained. It is composed of a container assembly which houses the solid state oxygen generator, an actuator assembly which is a manually controlled initiator for oxygen production and a conical oronasal face mask with accumulator bag. The entire system weighs 2.04 kg with overall dimensions of 36 cm length and 11 cm diameter.

The principle behind its operation is not new, having been employed at least since WW II as a means for producing oxygen onboard submarines, but only recently has this concept been adapted for utilization in the aviation industry. Solid state oxygen generators are composed of a chemical mixture enclosed within a metal canister. In the case of the Aviox generators, the major component of the chemical composition is sodium chlorate. Hence the name chlorate candle is derived and most commonly used when referring to the generators. Other chemicals are added to this composition as binders and fuel for the decomposition reaction and for removal of impurities in the product gas. The decomposition of the sodium chlorate liberates oxygen during an exothermic reaction($2NaClO_3$ + heat $\rightarrow 2NaCl + 3O_2$). The reaction is started by activating an enriched fuel area within the candle. This burns producing enough heat to raise the temperature of the chemical composition to a critical point whereby the degradation becomes self- sustaining.

Methods

The Scott Aviox Single Pak System (SCT-802501-15) and replacement generators (SCT-802111-00) were used during this experiment. This evaluation covered the operation of the unit and its performance under normal conditions and after exposures to temperature extremes. Unless specifically stated, all testing was conducted under normal atmospheric conditions of 740 mmHg±10 mmHg at room temperature 21-24 degrees C.

The first tests to be conducted were on twenty-five generators that had been received and stored under normal conditions. The first ten generators were activated and product gas samples were collected for comprehensive analysis. (The samples were taken during the first minute and at two minute intervals during the advertised production time.) The samples were analysed for oxygen (per cent), nitrogen (per cent), carbon monoxide (ppm), carbon dioxide (ppm), chlorine (ppm), methane (ppm), nitric oxide (ppm), nitrogen dioxide (ppm) and hydrocarbons. In addition, a comprehensive electron capture gas chromatographic and capillary separation with mass spectral identification analysis were conducted to determine what other contaminants were present.

A further 15 generators were activated and their time of activation, which was from depression of the initiator, until flow reached the requirement of USAF MIL-E-83252 was measured. Flow rates were recorded at one minute intervals using a Kurz Model 543 mass flow meter until the generator was expended. This total production time was also recorded. Product gas temperature was monitored using a Yellow Spring Instrument (YSI) thermister located downstream of the generator in the approximate location of the face mask. Matched YSI thermistors were attached to the outside generator housing and the temperature of the case monitored. In addition, the product gas oxygen concentration was monitored with a Biomarine OM-300 Oxygen Monitor.

The same monitoring process was used for generators exposed to cold temperatures. These units were exposed for 24 hours at -54 degrees C in a Cincinnati freezer. Groups of five generators were removed from the cold and activated; immediately and at 0.5 hrs., 4.0 hrs. and 24 hrs. after being returned to room temperature. An additional group of five generators were exposed to a cold cycle which consisted of exposure to -54 degrees C for eight hours with removal to room temperature for 16 hours. This was repeated for five days and the generators were activated at the end of the final 16 hour period.

The same procedure was repeated using a hot temperature of +65.5 degrees C. A total of 20 generators were placed in a Despatch Model 287 heating oven for 24 hours. They were removed to room temperature in groups of five and activated at the same time intervals as those subjected to cold. The heat cycle in this event consisted of exposing an additional five generators to +65.5 degrees C for eight hours then removing them to room temperature for 16 hours. This was repeated for five days and the generators activated at the end of the final 16 hour cooling period.

The entire assembly was stored in both temperature extremes for 24 hours. (This was repeated three times for each temperature.) At the end of this period they were removed, a generator was inserted and then activated to see what if any effect these temperatures had on the mechanical operation of the system.

To simulate an explosive decompression where cabin temperature would drop to ambient, the Cincinnati freezer was lowered to -48 degrees C. (Simulated ambient temperature at 32,000 feet.) The oxygen line was placed through an outlet port and attached to the monitoring equipment outside. The unit was then placed in the freezer and activated immediately. A total of five generators were tested in this manner.

The data recorded from each test lot was used in determining the mean flow rates asnd production time of the generators. These results were plotted in comparison with USAF MIL-E 83252, and the manufacturer's advertised production flow rate time. The performance of generators exposed to temperature extremes was also compared with flow rates from generators stored under normal conditions.

RESULTS and DISCUSSION

Results from product gas analysis presented in Table 1 show that all samples analysed met or exceeded the requirements established in USAF MIL-E-83252. This guideline does not establish a minimal level for percent oxygen, therefore, the advertised purity of 99.5% was used for comparison. Oxygen levels found in the analysis were comparable to this advertised rate with the exception of Sample 1. This sample was collected during initial activation of the generator and allowance was made for air (nitrogen) sealed in the generator during manufacture. (Reference MIL-E-83252 Page 6 para 3.6.2).

Oxygen levels were monitored on all generators activated. The levels observed varied from a low of 97% up to and exceeding the advertised rate of 99.5%. The lower values were not confined to generators exposed to temperature extremes but were noted at various times during the experiment. The majority of these lower readings were observed near the end of generator production and presently cannot be explained but is most likely attributed to the chemical compositions degredation.

The lower values of 97% oxygen monitored does not appear to be significant especially when related to an oxygen purity of 95% being acceptable with molecular sieve on board oxygen generators. In view of lower levels observed than what is advertised, it would be advisable for a lower limit to be established that would place a value on the minimal percent acceptable for oxygen in the product gas.

All units tested were observed for time of activation. USAF MIL-E-83252 establishes 2.5 seconds as the maximum time from activation until product gas flow reaches 4.2 LPM. The times recorded from all generators varied from a low of 1.5 seconds to a high of 6 seconds. There was no appreciable difference in activation times of

TABLE 1

General Analysis Results of Product Gas Samples

Sample No.	O_2%	N_2%	Cl_2(ppm)	CO(ppm)	CO_2(ppm)	NO(ppm)	N_2O(ppm)	CH_4(ppm)	Hydrocarbons
Mil Spec	-	(1)	0.2	(2)	(3)	-	-	-	-
1	97.5	2.13	ND*	0.36	2981.0	ND	ND	0.57	Those present were not positively identified. Amounts found were either trace or ppb levels.
2	99.8	0.12	ND	0.21	208.0	ND	ND	0.60	
3	98.4	1.53	ND	0.21	760.4	ND	Trace	0.30	
4	99.5	0.45	ND	0.40	363.5	ND	Trace	0.40	
5	99.4	0.52	ND	Trace	348.8	ND	Trace	Trace	
6	99.8	0.11	ND	ND	259.9	ND	ND	0.40	
7	99.9	0.10	ND	ND	192.3	ND	Trace	ND	
8	99.8	0.17	ND	Trace	215.1	ND	ND	Trace	
9	99.8	0.01	ND	Trace	203.4	ND	ND	Trace	
10	99.9	Trace	ND	ND	187.5	ND	ND	Trace	

NOTE: (1) = Allowance For Trapped Nitrogen During First 30 Seconds

(2) = 1200 ppm 1st Minute - 15 ppm Thereafter

(3) = 5000 ppm 1st Minute - 1000 ppm Thereafter

ND = None Detected

normal generators or those activated after exposure to temperature. The difference between actual activation times recorded and the guidelines are minimal, even in the longest time. The time of useful consciousness (approximately 40 seconds) at altitudes up to a maximum of 32,000 feet where these units will be employed, would be sufficient so that several additional seconds makes no appreciable difference.

Product gas temperatures monitored throughout all aspects of the experiment were found to be comparable with room temperature. The maximum recorded temperature for this gas was observed at 29 degrees C which is still within the requirement of not exceeding 8.3 degrees C above ambient.

Temperature recordings taken at various points on the generator housing varied between highs of 31.5 degrees C to 39 degrees C during production. The insulating characteristics of the system are very good in regards to heat transmittance. The housing becomes warm but not to a degree where it would cause discomfort. The design nature of the system is such, that the top portion of the housing is vented to allow heat transfer to ambient. The escaping heat has a tendency to warm the systems initiator mechanism to a point where contact could produce a burn. Temperatures taken on the top portion of the initiator mechanism reached 85 degrees C. Contact would have to be avoided with bare skin, a gloved hand (normal flying glove) has no problem removing the initiator mechanism for generator replacement and would provide sufficient protection.

Oxygen production time of these generators is advertised as approximately 20 minutes. This is below the time limit of 30 minutes established in USAF MIL-E-83252 but deemed to be a sufficient amount of time for most cases. If additional time is required, extra generators will have to be available. These can be placed into use extremely quickly without an extended interruption of flow.

A noticeable effect on production time was noted in generators exposed to the hot and cold extremes. Table 2 shows the minimum, mean and maximum production times for each group of generators tested. Exposure to heat and cold affected the production time of generators quite extensively if activated immediately after removal from storage. In those cases, the heat exposure reduced production time to approximately 17 mninutes whereby cold exposure prolonged production to approximately 28 minutes. In operation it is extremely unlikely that units would be exposed to such extremes of temperature. It is more likely that cabin temperature would stabilize and warm or cool the unit sufficiently to return production to normal before an altitude would be encountered that necessitated their use. The effect of heat on production time is of no consequence if additional generators are carried. The generators would have to be replaced sooner than the expected 20 minutes.

The requirement for flow rate production is established in USAF MIL-E-83252 as 4.2 LPM during the initial 3 minutes of production, dropping to 2.5 LPM for the duration of the generator (30 minutes). The advertised rate is 4.3 LPM (NTPD). Actual flow rate production recorded from generators stored under normal conditions

TABLE 2

Recorded Production Times of Scott Aviox(R) Solid State Oxygen Generators

Test Lot	Advertised Time	Minimum Time Recorded	Maximum Time Recorded	Average ($\bar{X}$) Production Time
Normal	20 min	19 min 20 sec	22 min 34 sec	21 min 01 sec
Cold Environment Test -48.5°C	-	21 min 30 sec	22 min 10 sec	21 min 45 sec
-54°C for 24 hours fired immediately on removal	-	26 min 30 sec	31 min 25 sec	28 min 40 sec
-54°C for 24 hours fired .5 hour after removal	-	25 min 12 sec	28 min 30 sec	26 min 37 sec
-54°C for 24 hours fired 4 hours after removal	-	20 min 45 sec	22 min 15 sec	21 min 24 sec
-54°C for 24 hours fired 24 hours after removal	-	16 min 15 sec	21 min 03 sec	19 min 09 sec
Cold Soak Cycle -54°C	-	21 min 20 sec	22 min 46 sec	21 min 34 sec
+65.5°C for 24 hours fired immediately on removal	-	16 min 32 sec	17 min 30 sec	17 min 08 sec
+65.5°C for 24 hours fired .5 hour after removal	-	19 min 54 sec	20 min 54 sec	20 min 36 sec
+65.5°C for 24 hours fired 4 hours after removal	-	21 min 12 sec	22 min 50 sec	21 min 46 sec
+65.5°C for 24 hours fired 24 hours after removal	-	21 min 52 sec	23 min 19 sec	22 min 29 sec
Heat Soak Cycle +65.5°C	-	20 min 40 sec	22 min 40 sec	21 min 36 sec

exceeded this value. Tables 3 - 14 shows the average flowrates by minute of production time for the advertised 20 minutes for all test lots in this experiment. This data is plotted in graphical form (mean production LPM ± standard deviations versus production time) in Annex A Figures 1-12.

Exposure to temperature extremes altered the flowrate production from the normal results. The major differences were observed in generators activated immediately or shortly after removal from the storage environment. In the case of generators exposed to heat, the difference was an increase in flowrate production at the expense of production time. In generators exposed to the cold storage environment, there was a marked decrease in the flow rates obtained from generators fired immediately and shortly after removal. The flow rates still exceeded the requirement with the exception of one generator activated immediately after removal. During the third minute of production, it fell to 4.0 LPM versus 4.2 LPM. This worst case will probably not be encountered as it is envisioned the unit will not be required immediately after coming out of a cold storage situation. The system would be warmed with the rise in temperatures within the aircraft prior to reaching an altitude where supplemental oxygen would be required.

The results of the operation in a cold environment test are shown in Table 4 and plotted with advertised and required production in Figure 2. There were only minor differences in flow rate and production times of these units as compared to normal results. Its operation is not impeded by the temperature change which could be expected with the worst case of decompression.

The housing assembly and initiating mechanism were exposed to both temperature extremes (-54 and +65.5 degrees C) for 24 hours. On immediate removal the system was fitted with a generator and actuated. The temperature had no effect on the system's ability to fire the initiating mechanism or its removal for generator replacement.

CONCLUSIONS and RECOMMENDATIONS

In summary, a total of 85 chemical oxygen generators were tested for performance under normal and temperature extremes that may be encountered during operational use in the LRPA. Analysis of samples show that the product gas purity is such that it meets the criteria established in MIL-E-83252. Overall flow rate results indicate that short term exposures to temperature extremes had no significant effect on the units ability to perform to the required standards. Based on the results and pending hypobaric chamber evaluation, the unit is considered quite satisfactory for producing supplemental oxygen to crew members in the new LRPA. However, it is recommended that:

a. If the systems stored in aircraft are expected to be exposed to temperature extremes for extended periods of time (i.e. long periods of shutdown or extended maintenance), they should be removed and placed in the storage temperatures suggested by the manufacturer.

b. Extra generators should be carried onboard the aircraft to replace expended generators, in the event that supplemental oxygen is required in excess of 20 minutes.

c. A suitable container should be available in the aircraft for the disposal of hot expended generators.

d. Operational instructions regarding this system should include procedures for the removal of hot expended generators.

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3. deSteigver, D., E.B. McFadden and Jim Simpson. Characteristics of Portable First-Aid Chemical Oxygen Generators. Proceedings of the 11th Annual SAFE Symposium, Phoenix, Arizona, October 1973.

4. MIL-E-83252 (USAF) Military Specification; Emergency Oxygen Supply Chlorate Candle, Aircraft CRU-78/P 20 February 1970.

TABLE 3

AVERAGE FLOW (LPM, NTP) ± STANDARD DEVIATION FROM GENERATORS STORED UNDER NORMAL CONDITIONS (N=15)

Minute	Average Flow ± S.D.	Minute	Average Flow ± S.D.
1	7.85 ± .57	11	6.09 ± .45
2	6.17 ± .57	12	6.23 ± .51
3	5.65 ± .49	13	6.11 ± .39
4	5.83 ± .60	14	6.20 ± .39
5	6.12 ± .48	15	6.17 ± .45
6	6.39 ± .46	16	6.16 ± .54
7	6.47 ± .41	17	6.16 ± .80
8	6.35 ± .41	18	6.15 ± .73
9	6.26 ± .41	19	5.90 ± .69
10	6.27 ± .52	20	5.30 ± .71*

*N=14

TABLE 4

AVERAGE FLOW (LPM, NTP) ± STANDARD DEVIATION FROM GENERATORS ACTIVATED IN A COLD ENVIRONMENT OF $-48.5^{\circ}C$ (N=5)

Minute	Average Flow ± S.D.	Minute	Average Flow ± S.D.
1	7.66 ± .35	11	6.08 ± .31
2	6.16 ± .23	12	6.41 ± .57
3	5.74 ± .44	13	6.10 ± .28
4	5.90 ± .54	14	6.42 ± .27
5	6.32 ± .20	15	6.45 ± .61
6	6.47 ± .37	16	5.97 ± .58
7	7.05 ± .08	17	6.02 ± .66
8	6.98 ± .27	18	6.23 ± 1.03
9	6.84 ± .38	19	6.44 ± .72
10	6.24 ± .57	20	6.16 ± .90

TABLE 5

AVERAGE FLOW (LPM, NTP) ± STANDARD DEVIATION FROM GENERATORS EXPOSED TO -54°C FOR 24 HRS AND ACTIVATED IMMEDIATELY AFTER (N=5)

Minute	Average Flow ± S.D.	Minute	Average Flow ± S.D.
1	6.84 ± .52	11	4.75 ± .54
2	5.80 ± .35	12	4.57 ± .65
3	4.36 ± .28	13	5.51 ± .42
4	3.74 ± .52	14	4.97 ± .62
5	3.80 ± .76	15	5.22 ± .67
6	3.65 ± .62	16	5.61 ± .58
7	4.10 ± .56	17	5.44 ± .54
8	4.18 ± .95	18	5.76 ± .50
9	3.89 ± .62	19	5.80 ± 1.30
10	4.64 ± .51	20	5.62 ± .78

TABLE 6

AVERAGE FLOW (LPM, NTP) ± STANDARD DEVIATION FROM GENERATORS EXPOSED TO -54°C FOR 24 HRS AND ACTIVATED .5 HRS AFTER (N=5)

Minute	Average Flow ± S.D.	Minute	Average Flow ± S.D.
1	6.88 ± .38	11	5.06 ± .52
2	5.40 ± .39	12	4.86 ± .84
3	4.64 ± .13	13	5.00 ± .33
4	4.10 ± .68	14	4.75 ± .46
5	4.63 ± .51	15	4.93 ± .29
6	4.50 ± .87	16	5.15 ± .39
7	4.40 ± .65	17	4.86 ± .34
8	4.48 ± .85	18	5.13 ± .48
9	5.00 ± .38	19	5.09 ± .44
10	4.46 ± .85	20	4.93 ± .52

TABLE 7

AVERAGE FLOW (LPM, NTP) ± STANDARD DEVIATION FROM GENERATORS EXPOSED TO -54°C for 24 HOURS AND ACTIVATED 4 HOURS LATER

(N=5)

Minute	Average Flow ± S.D.	Minute	Average Flow ± S.D.
1	7.30 ± .09	11	5.76 ± .58
2	5.87 ± .46	12	6.06 ± .55
3	4.86 ± .21	13	5.72 ± .35
4	5.36 ± .35	14	5.99 ± .38
5	5.58 ± .28	15	6.05 ± .24
6	6.16 ± .13	16	6.08 ± .28
7	6.34 ± .21	17	6.01 ± .47
8	6.41 ± .42	18	6.37 ± .20
9	6.34 ± .64	19	6.16 ± .27
10	5.98 ± .38	20	5.62 ± .18

TABLE 8

AVERAGE FLOW (LPM, NTP) ± STANDARD DEVIATION FROM GENERATORS EXPOSED TO -54°C FOR 24 HRS AND ACTIVATED 24 HRS AFTER

(N=5)

Minute	Average Flow ± S.D.	Minute	Average Flow ± S.D.
1	6.74 ± .77	11	5.76 ± .69
2	5.44 ± .66	12	6.01 ± .21
3	5.44 ± 1.10	13	5.87 ± .48
4	5.80 ± .68	14	5.72 ± .56
5	6.37 ± .97	15	5.87 ± .37
6	6.30 ± .84	16	5.33 ± .61
7	6.12 ± .70	17	5.22 ± .67*
8	6.19 ± .89	18	5.45 ± .15*
9	6.05 ± .53	19	5.04 ± .39*
10	6.12 ± .43	20	4.68 ± .18*

*N=4

TABLE 9

AVERAGE FLOW (LPM, NTP) AND STANDARD DEVIATIONS FROM GENERATORS EXPOSED TO -54°C DURING COLD CYCLING (N=5)

Minute	Average Flow ± S.D.	Minute	Average Flow ± S.D.
1	8.15 ± .45	11	6.12 ± .28
2	6.73 ± .09	12	5.87 ± .33
3	6.01 ± .49	13	6.05 ± .22
4	6.19 ± .40	14	5.83 ± .66
5	6.62 ± .49	15	5.80 ± .24
6	6.66 ± .41	16	5.72 ± .13
7	7.27 ± .49	17	5.58 ± .30
8	7.24 ± .53	18	5.80 ± .24
9	6.88 ± .53	19	5.58 ± .18
10	6.19 ± .29	20	5.26 ± .31

TABLE 10

AVERAGE FLOW (LPM, NTP) ± STANDARD DEVIATIONS FROM GENERATORS EXPOSED TO + 65.5°C FOR 24 HOURS AND ACTIVATED IMMEDIATELY (N=5)

Minute	Average Flow ± S.D.	Minute	Average Flow ± S.D.
1	8.80 ± .37	11	7.43 ± .37
2	7.29 ± .32	12	7.01 ± .48
3	7.06 ± .49	13	7.45 ± .80
4	7.47 ± .56	14	7.34 ± .46
5	7.80 ± .90	15	7.13 ± .89
6	7.81 ± .35	16	6.18 ± .55
7	8.03 ± .14	17	6.39 ± .66*
8	7.94 ± .71		
9	7.56 ± .44		
10	7.60 ± .42		

*N=4

TABLE 11

AVERAGE FLOW (LPM, NTP) ± STANDARD DEVIATIONS FROM GENERATORS EXPOSED TO +65.5°C FOR 24 HRS AND ACTIVATED .5 HRS AFTER (N=5)

Minute	Average Flow ± S.D.	Minute	Average Flow ± S.D.
1	7.60 ± .50	11	5.85 ± .41
2	6.39 ± .40	12	5.96 ± .54
3	6.10 ± .36	13	5.99 ± .54
4	6.82 ± .48	14	5.95 ± .53
5	6.68 ± .57	15	5.85 ± .60
6	6.93 ± .77	16	5.89 ± .48
7	6.97 ± .92	17	5.67 ± .49
8	6.62 ± .80	18	5.31 ± .24
9	6.45 ± .61	19	4.93 ± .28
10	6.11 ± .56	20	4.28 ± .72*

*N=4

TABLE 12

AVERAGE FLOW (LPM, NTP) ± STANDARD DEVIATIONS FROM GENERATORS EXPOSED TO +65.5°C FOR 24 HRS AND ACTIVATED 4 HRS AFTER (N=5)

Minute	Average Flow ± S.D.	Minute	Average Flow ± S.D.
1	7.63 ± .37	11	5.90 ± .48
2	6.17 ± .12	12	5.75 ± .15
3	5.63 ± .37	13	5.80 ± .36
4	6.25 ± .50	14	5.80 ± .35
5	6.41 ± .38	15	5.80 ± .39
6	6.66 ± .49	16	5.58 ± .57
7	7.12 ± .42	17	5.71 ± .34
8	7.15 ± .29	18	5.74 ± .38
9	6.44 ± .23	19	5.45 ± .25
10	6.21 ± .27	20	4.97 ± .14

TABLE 13

AVERAGE FLOW (LPM, NTP) ± STANDARD DEVIATION FROM GENERATORS EXPOSED TO +65.5°C FOR 24 HRS AND ACTIVATED 24 HRS AFTER (N=5)

Minute	Average Flow ± S.D.	Minute	Average Flow ± S.D.
1	7.58 ± .43	11	5.69 ± .27
2	6.46 ± .34	12	5.86 ± .29
3	5.44 ± .38	13	5.42 ± .69
4	6.09 ± .40	14	5.85 ± .41
5	6.28 ± .46	15	5.80 ± .31
6	6.57 ± .67	16	5.67 ± .27
7	6.81 ± .53	17	5.74 ± .19
8	6.85 ± .39	18	5.53 ± .50
9	6.59 ± .37	19	5.27 ± .33
10	5.72 ± .52	20	5.22 ± .36

TABLE 14

AVERAGE FLOW (LPM, NTP) ± STANDARD DEVIATIONS FROM GENERATORS EXPOSED TO +65.5°C DURING HEAT CYCLING - (N=5)

Minute	Average Flow ± S.D.	Minute	Average Flow ± S.D.
1	7.70 ± .42	11	6.19 ± .18
2	6.34 ± .40	12	5.58 ± .30
3	5.81 ± .29	13	5.76 ± .41
4	6.08 ± .66	14	5.65 ± .25
5	6.23 ± .46	15	5.83 ± .24
6	6.80 ± .38	16	5.44 ± .26
7	6.82 ± .42	17	5.54 ± .26
8	6.66 ± .30	18	5.58 ± .23
9	6.62 ± .52	19	5.47 ± .25
10	5.98 ± .24	20	5.29 ± .37

TABLE OF FIGURES

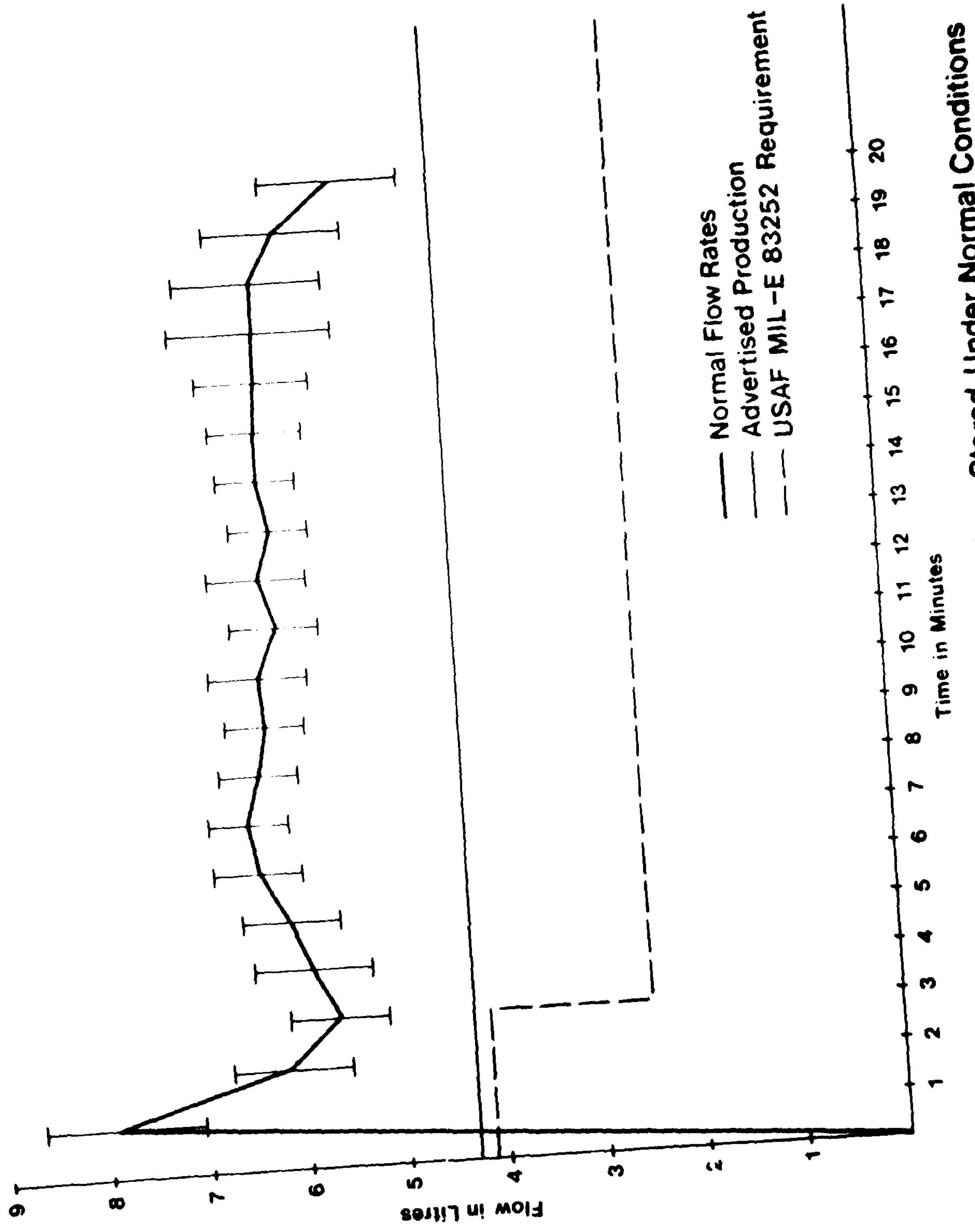

Figure 1 Flow Rate Production of Generators Stored Under Normal Conditions

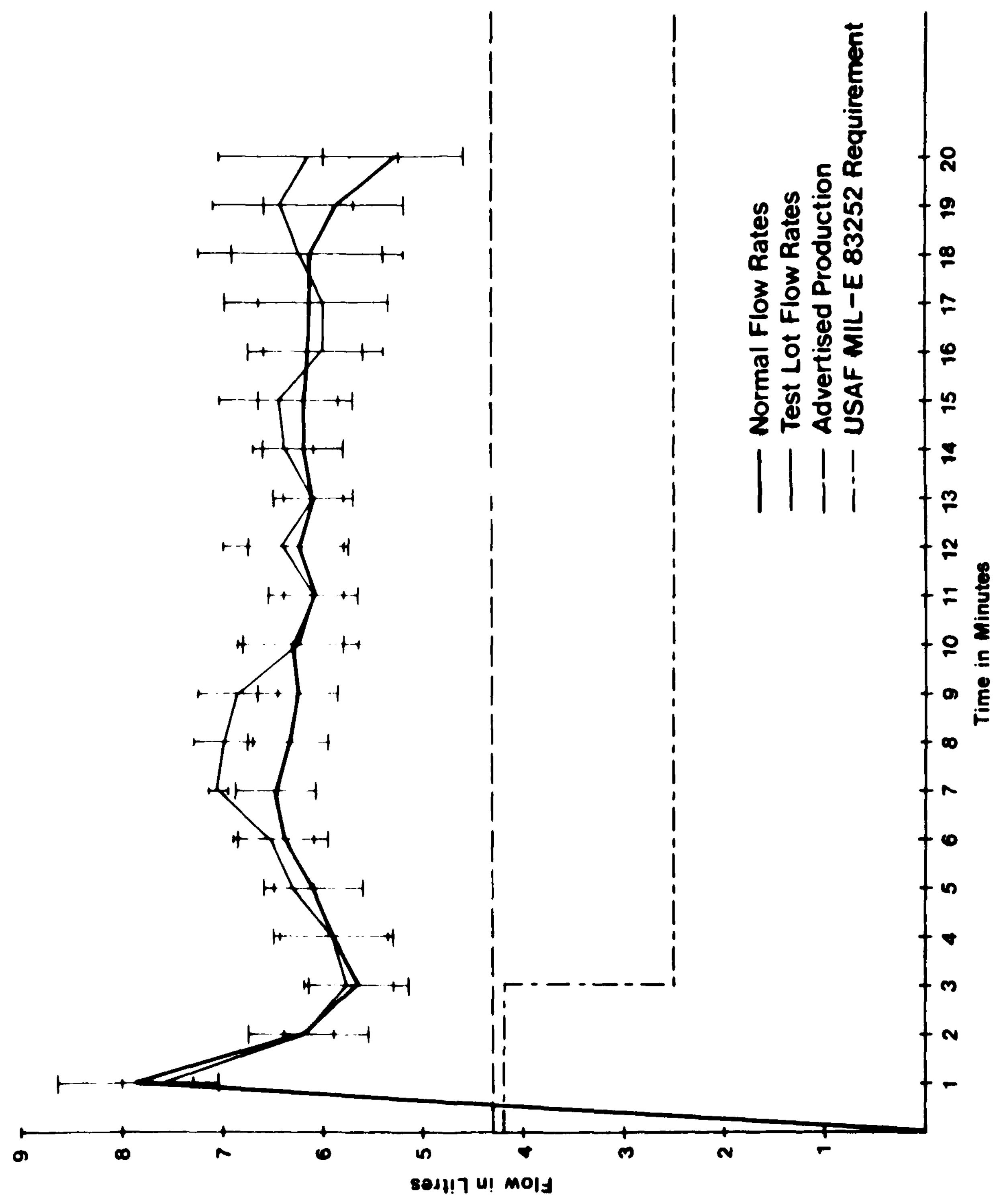

Figure 2 Flow Rate Production of Generators Activated in a Cold Environment –48.5°C

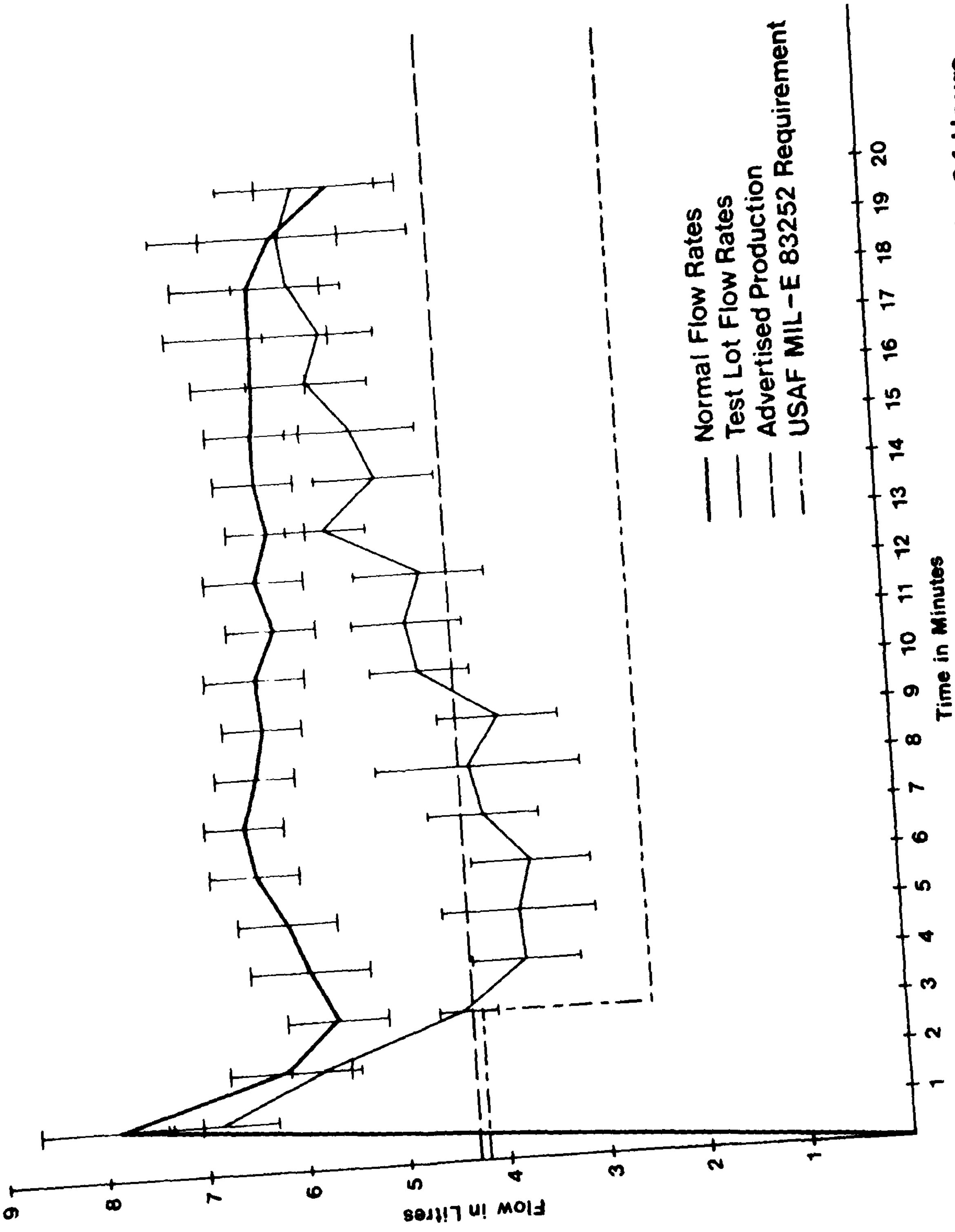

Figure 3 Flow Rate Production of Generators Stored at −54°C for 24 Hours and Activated Immediately After Removal

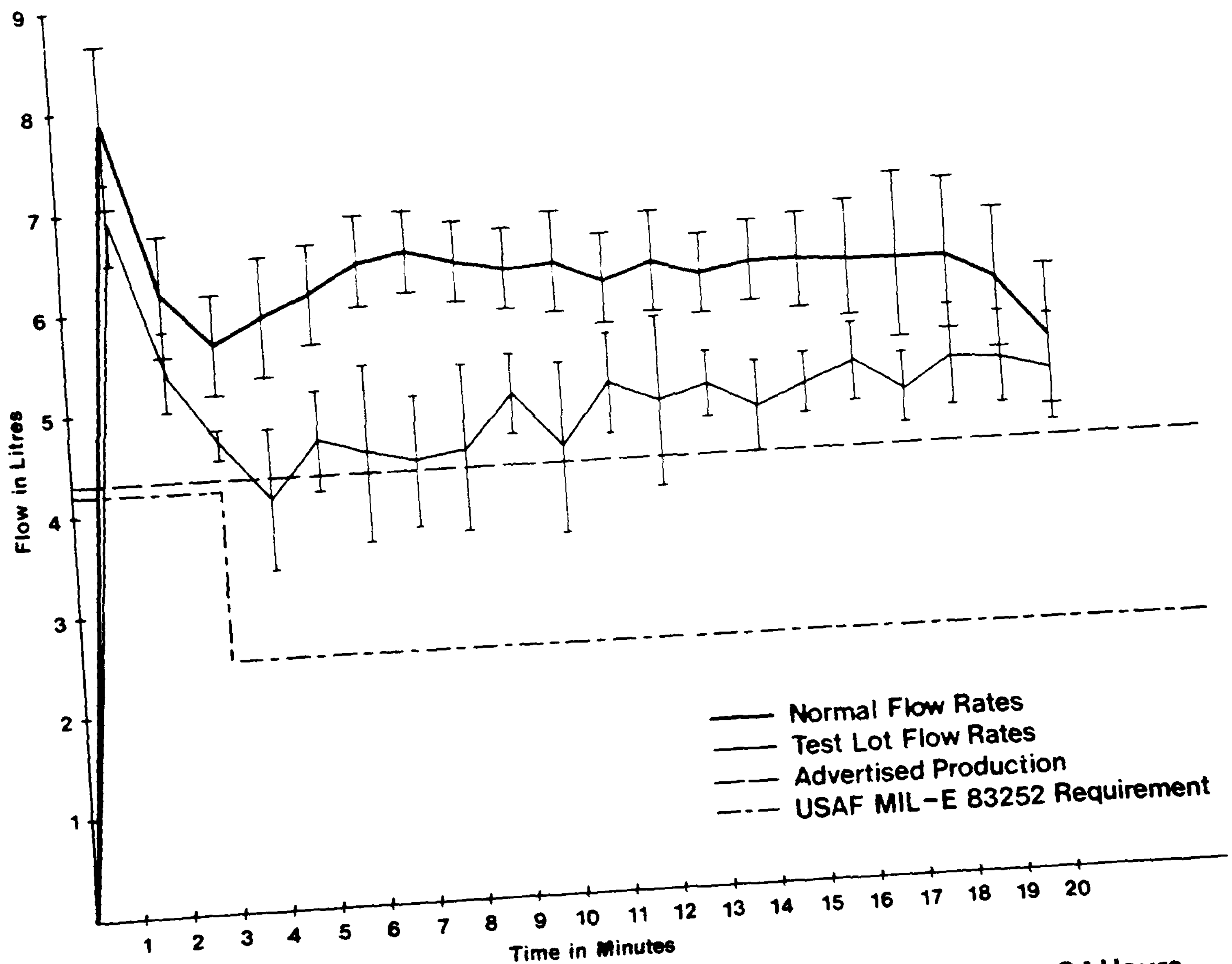

Figure 4 Flow Rate Production of Generators Stored at −54°C for 24 Hours and Activated .5 Hours After Removal

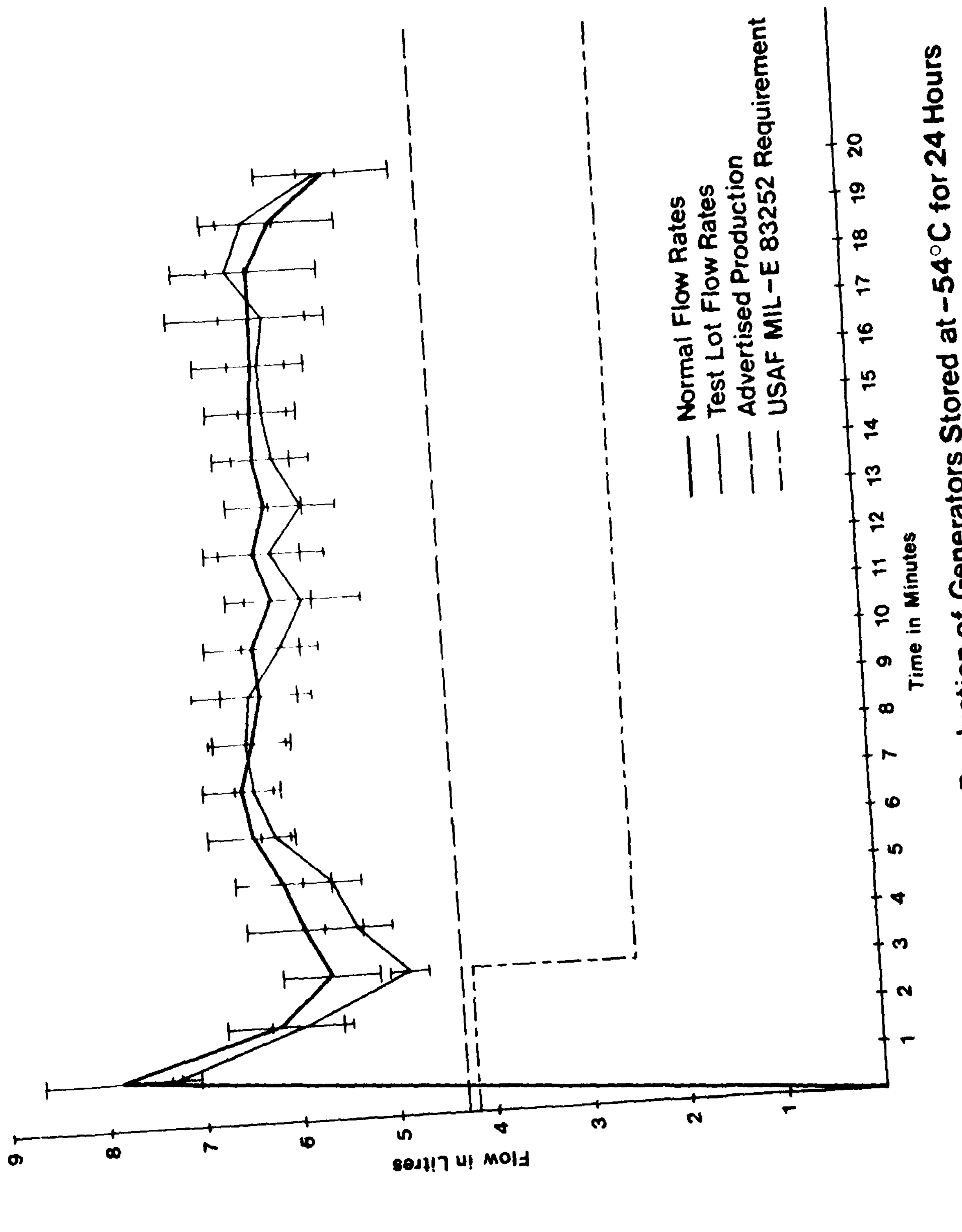

Figure 5 Flow Rate Production of Generators Stored at −54°C for 24 Hours and Activated 4 Hours After Removal

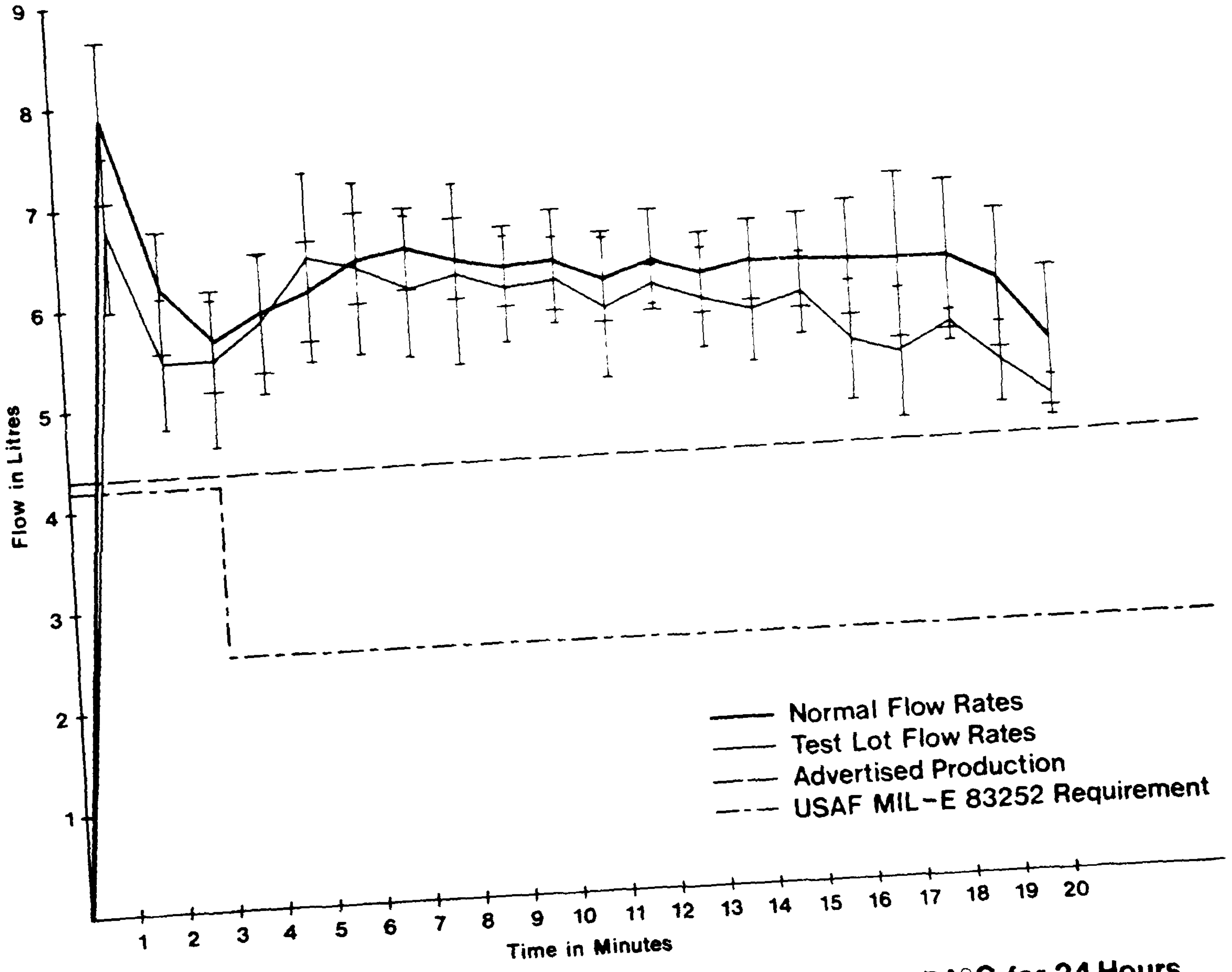

Figure 6 Flow Rate Production of Generators Stored at $-54°C$ for 24 Hours and Activated 24 Hours After Removal

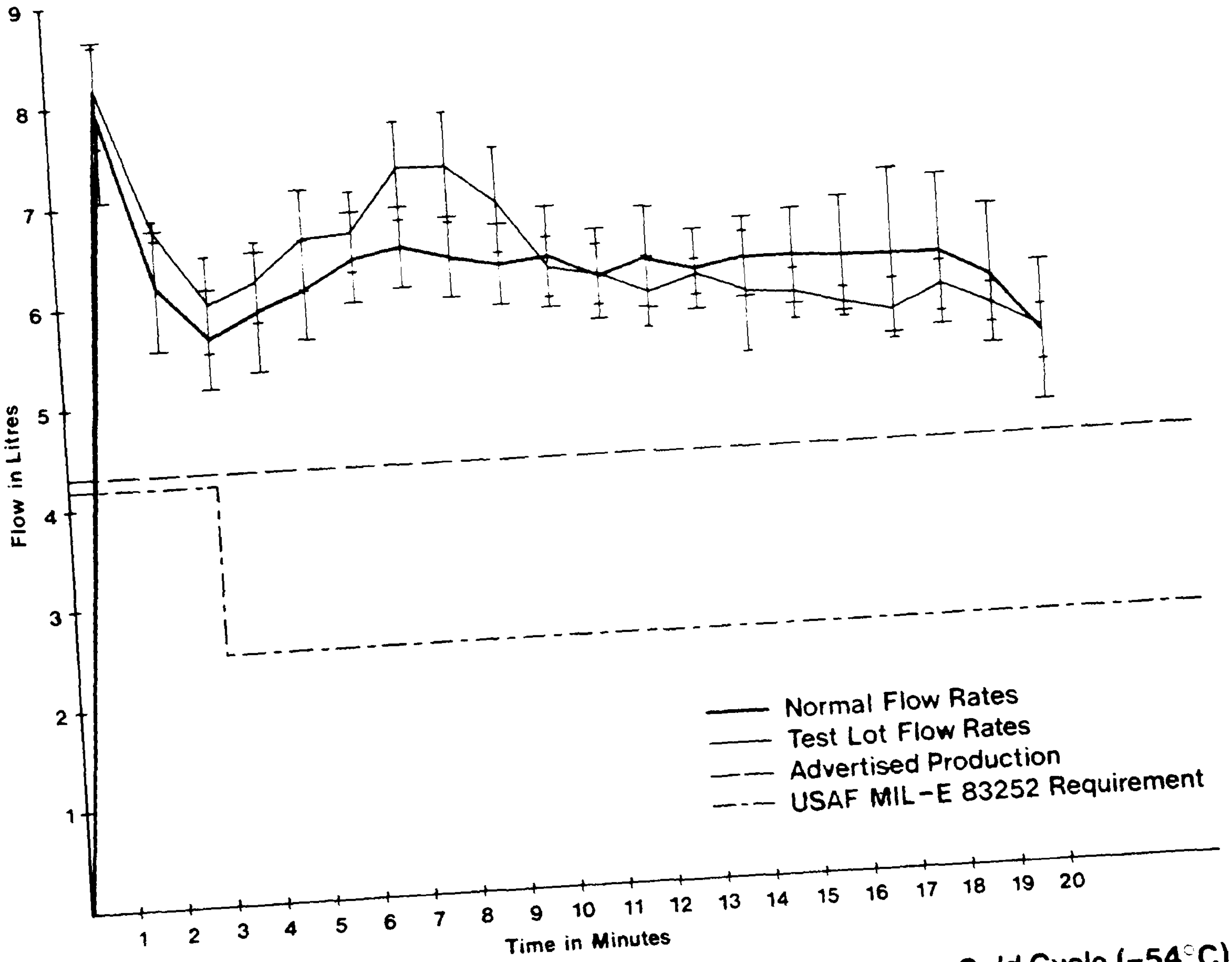

Figure 7 Flow Rate Production of Generators Exposed to a Cold Cycle (−54°C)

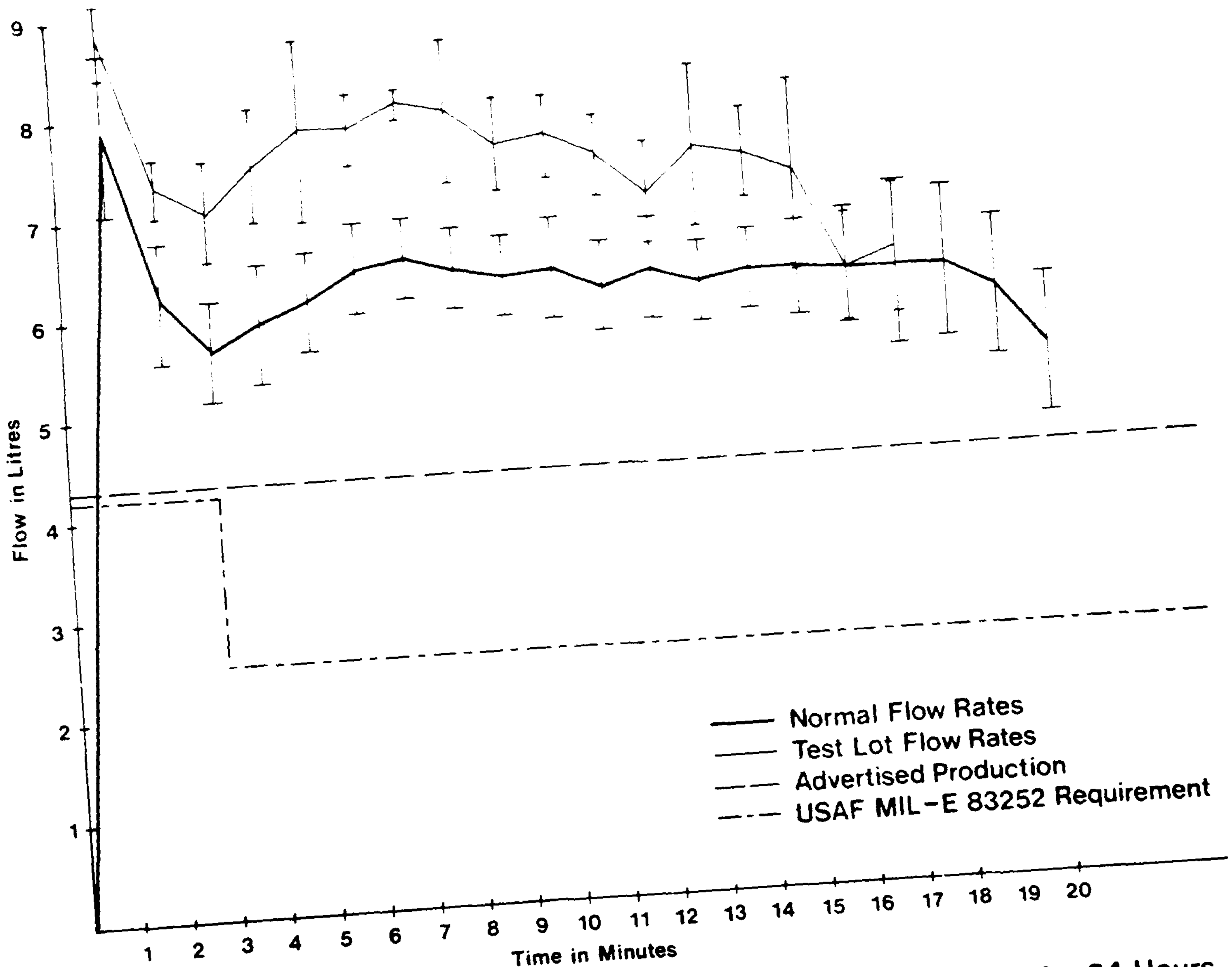

Figure 8 Flow Rate Production of Generators Stored at +65.5°C for 24 Hours and Activated Immediately After Removal

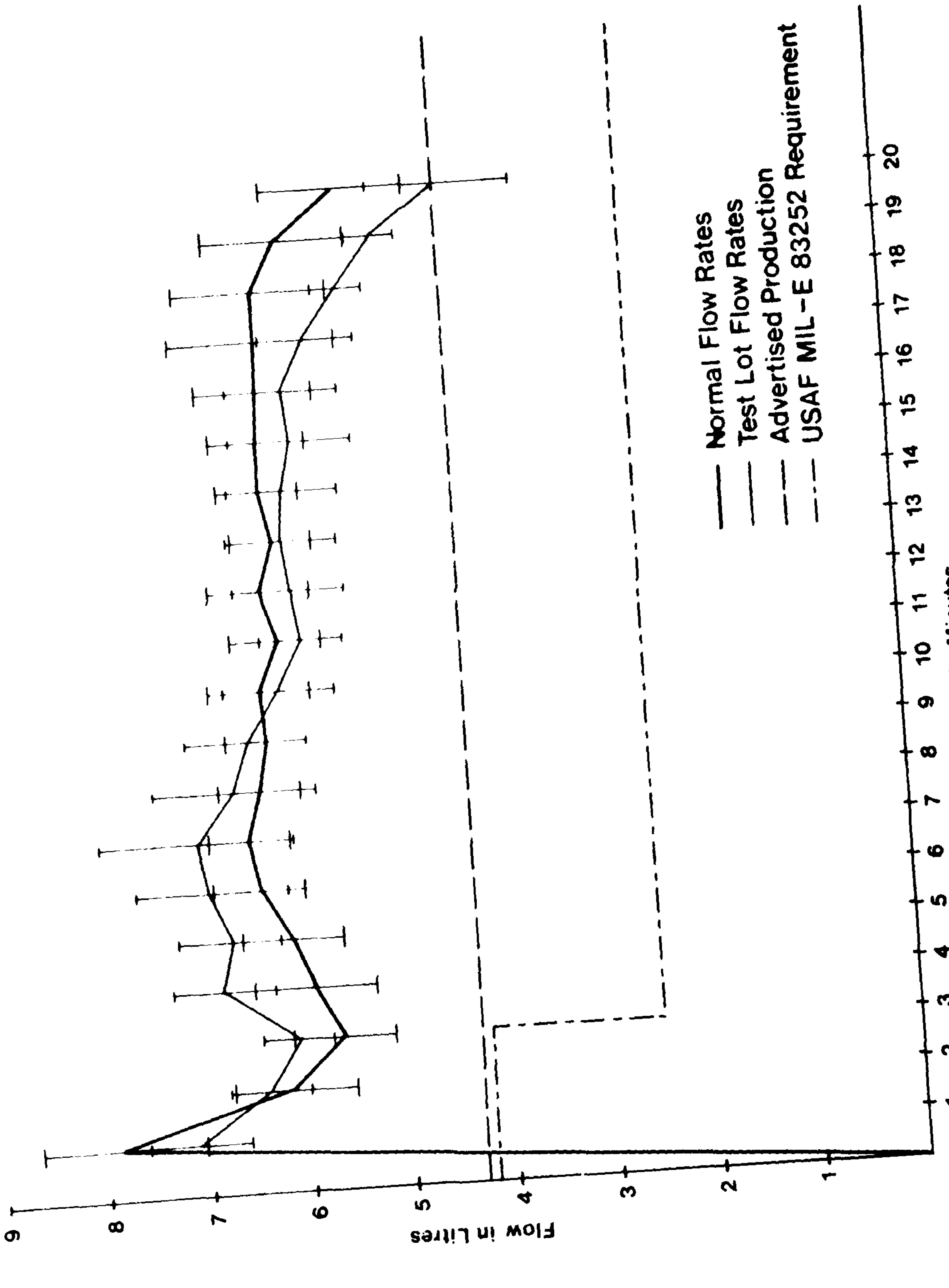

Figure 9 Flow Rate Production of Generators Stored at +65.5°C for 24 Hours and Activated .5 Hours After Removal

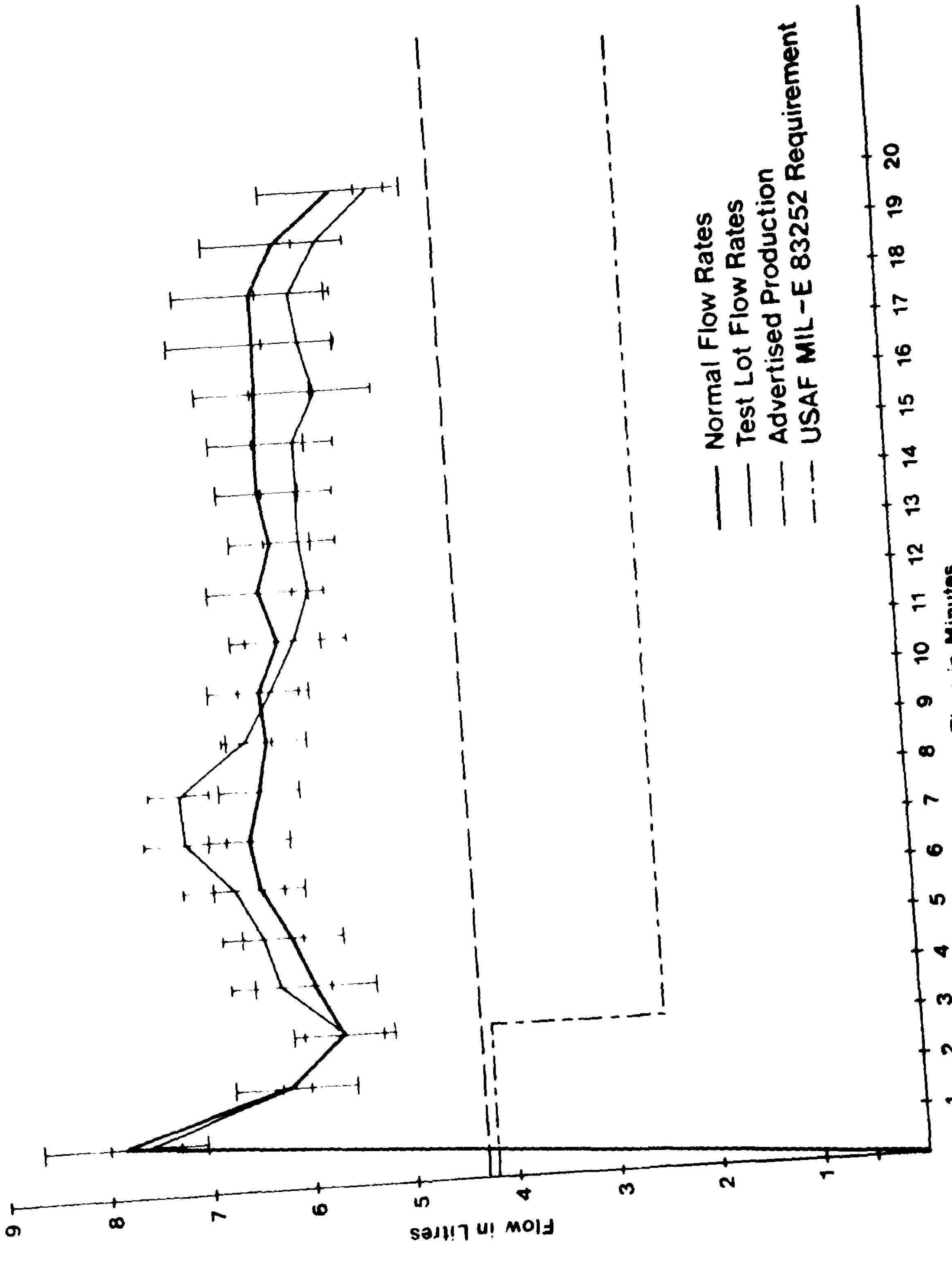

Figure 10 Flow Rate Production of Generators Stored at +65.5C for 24 Hours and Activated 4 Hours After Removal

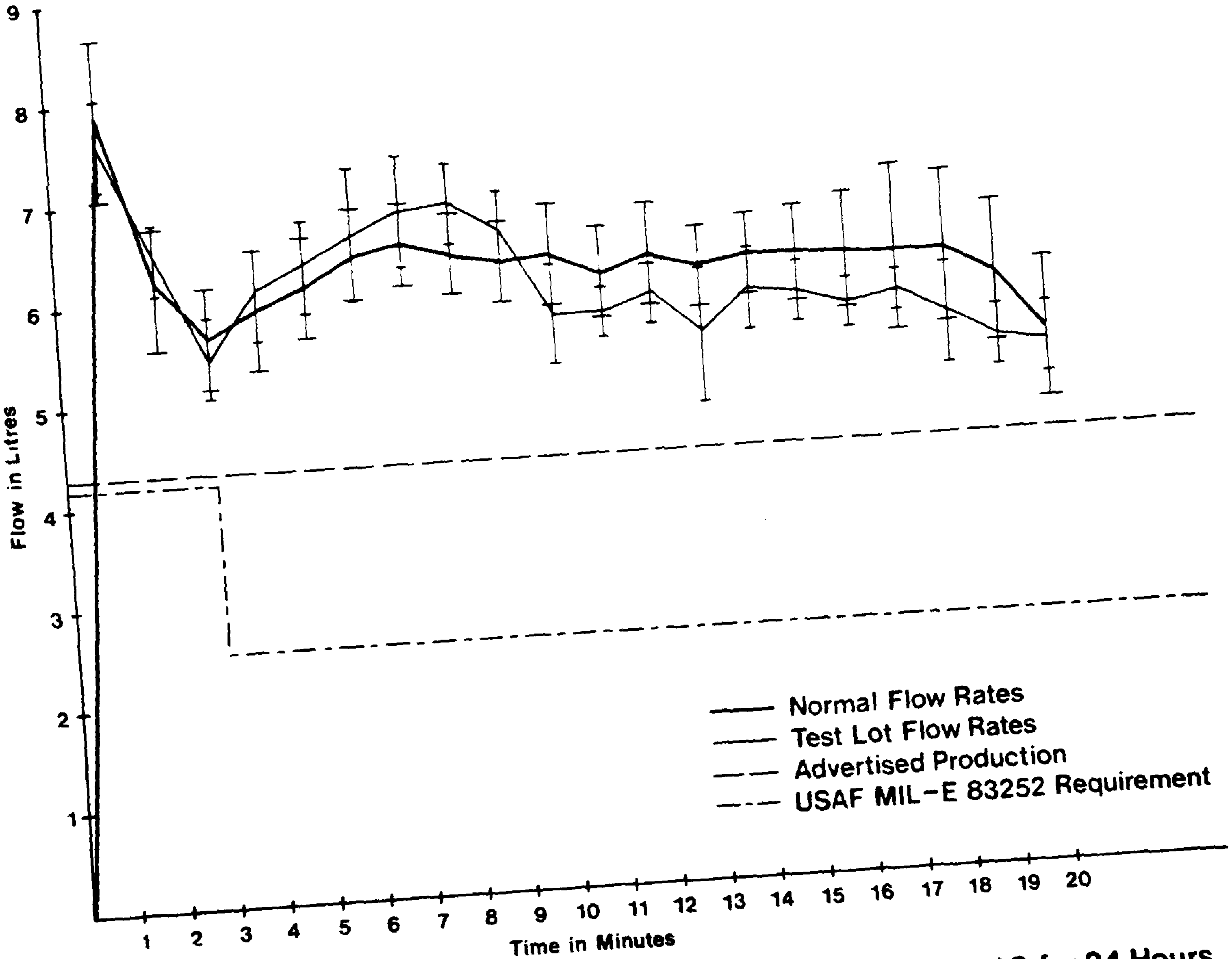

Figure 11 Flow Rate Production of Generators Stored at +65.5°C for 24 Hours and Activated 24 Hours After Removal

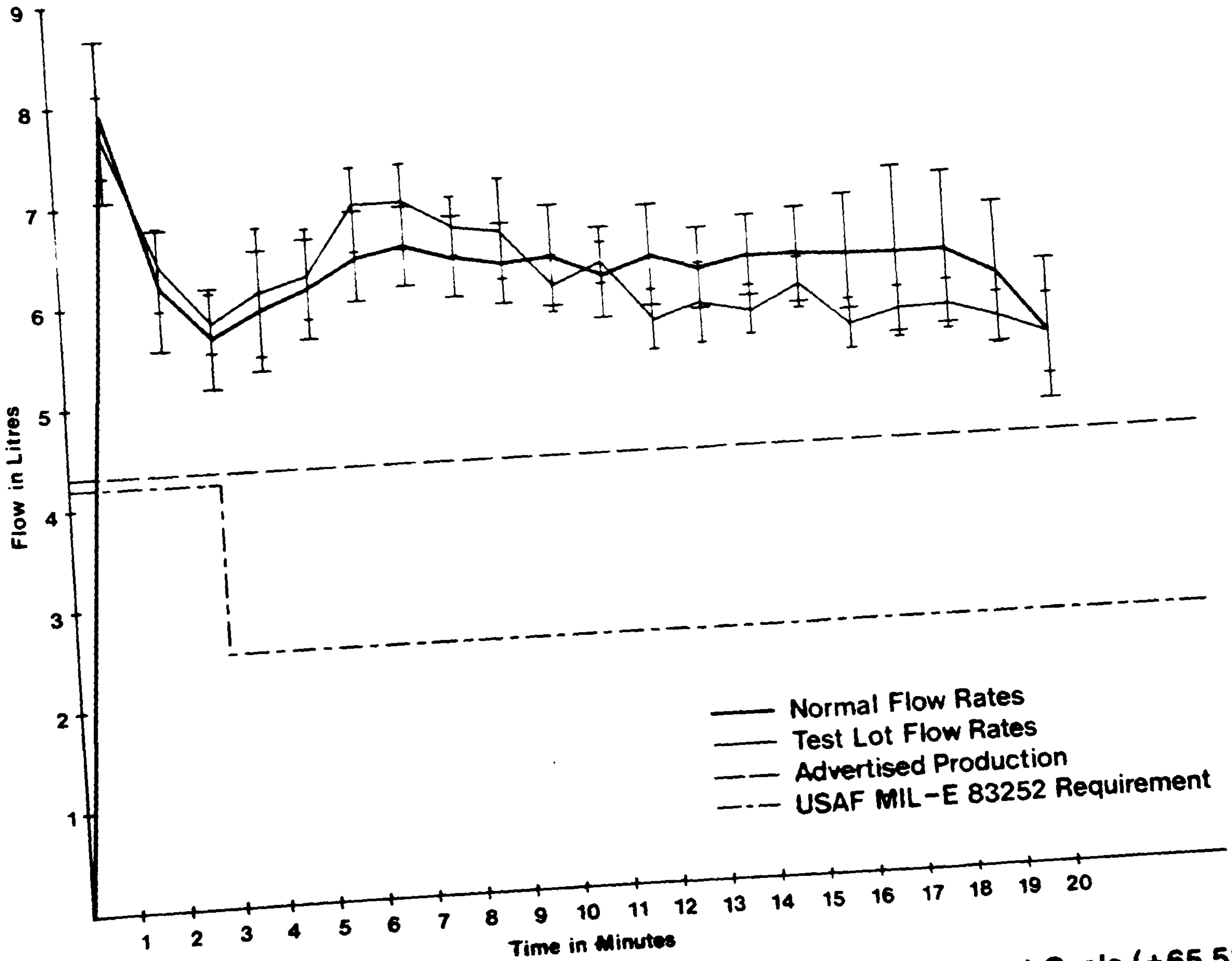

Figure 12 Flow Rate Production of Generators Exposed to a Heat Cycle (+65.5°C)